EFFICACY OF ORTHENE® FOREST SPRAY, DYLOX 4®, AND SEVIN® 4 OIL IN CONTROLLING SPRUCE BUDWORM

A Pilot Control Project
Maine, 1976

U.S. Department of Agriculture, Forest Service, State & Private Forestry,
Northeastern Area, Broomall, Pa. 19008

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CONTENTS

PREFACE

Orthene[1/] Forest Spray, Dylox 4[1/] and Sevin 4 Oil[1/] were aerially applied to large blocks of balsam fir in Maine to determine the effectiveness of the insecticides in reducing spruce budworm populations and in saving foliage. Samples (15-inch branch tips)[2/] were taken before and after spraying to determine percentage of budworm mortality. Two tips were cut from the midcrown of each of 540 dominant sample trees. Defoliation was estimated on the same trees when the budworm larvae finished feeding.

When budworm larvae were in the fourth instar (June 3, 1976), PV-2 aircraft applied the following treatments:

Orthene Forest Spray - 64 oz/acre; 8 oz/acre active acephate

Dylox 4 - 12.5 oz/acre; 4.1 oz/acre active trichlorfon

Sevin 4 Oil - 27 oz/acre; 10.8 oz/acre active carbaryl

Each treatment and an untreated check block was replicated three times.

1/ Use of trade, firm or corporation names in this paper is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U. S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.

2/ All conversions to approximate metric or United States values are on pages 51 and 52.

Covariance analysis showed the following percentage of budworm mortality:

Orthene Forest Spray, 99

Sevin-4 Oil, 51

Dylox 4, 34

Estimates of foliage saved by treatment were:

Orthene Forest Spray, 34 percent

Sevin 4 Oil, 17 percent

Dylox 4, 9 percent

This report contains a detailed description of the sampling and spraying methods used to determine efficacy of the insecticides. Two ancillary evaluations made during this project - analysis of spray deposit and methods for estimating defoliation - are reported in Appendix A and B.

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EFFICACY OF ORTHENE(R) FOREST SPRAY, DYLOX 4(R) AND SEVIN(R) 4 OIL IN CONTROLLING SPRUCE BUDWORM

INTRODUCTION

Balsam fir (Abies balsamea (L.)Mill.) and spruce (Picea spp.) are among the tree species susceptible to defoliation by spruce budworm (Choristoneura fumiferana (Clem.)). The insect has been at outbreak levels in Maine since 1968.

Insecticides applied by aircraft are often used to reduce budworm populations when trees are threatened and when budworm feeding is expected to continue. The magnitude of suppression projects requires the most economical methods be used to reduce the population while having as little impact on non-target organisms as possible. It is necessary to reduce dosages of registered insecticides and to test new chemicals that will help reach the goal of environmentally safe, economically sound, and biologically effective spruce budworm control.

In 1976, three insecticides were pilot tested against the spruce budworm in Maine. The tests simulated a normal operation in that large acreages were treated, application techniques were duplicated, and sampling methods, for efficacy, were similar. Two of the insecticides, Dylox 4 and Sevin 4 Oil, are registered at one pound active ingredient (trichlorfon and carbaryl respectively) an acre for budworm control.

The third, Orthene Forest Spray (with acephate as the active ingredient) is not registered, but had been used in Maine in a small field test. We tested reduced dosage and application rates of Dylox 4 and Sevin 4 Oil, and the rate of Orthene Forest Spray shown to be effective in the small test mentioned above.

Our objective was to determine, in terms of budworm population reduction and foliage saved, the efficacy of single aerial applications of:

8 ounces active acephate (Orthene Forest Spray) in water to make 0.5 gallons/acre.

12 ounces active trichlorfon (Dylox 4) in alcohol (Hi-Sol 4,5T$^{(R)}$) to make one quart/acre.

12 ounces active carbaryl (Sevin 4 Oil) in kerosene to make one quart/acre.

METHODS AND MATERIALS

Twelve blocks, each 1600 acres (15,840 feet by 4,400 feet) were established in the balsam fir - spruce forests near Oxbow, Maine (Figure 1). Each block corner was marked with a 2 feet by 3 feet fluorescent plastic flag stapled to a frame and fixed to a large tree so as to project above the canopy.

Fifteen clusters of three dominant or co-dominant balsam fir sample trees were tagged and numbered in each block. The clusters were distributed across the block so that several spray swaths would be sampled. Trees in a cluster were about 3 to 100 feet apart. Sample trees had some feeding by budworm in 1975, a 60-90 percent live crown ratio, and were less than 50 feet tall.

Drop cloths (one yard^2) were pegged to the ground under some sample trees (three cloths/block) to catch Arthropods that fell after being sprayed. The catch was collected five days after spray application, then classified.

Spray deposit cards were used as an aid in evaluating spray application (Appendix A).

Two branch tips were cut from the midcrown of each sample tree 2 days before spraying; and at 3, 7, and 14 days after spraying. The mean number of budworm larvae 15-inch branch was the basic unit used for calculating budworm population changes.

Prespray branch samples were examined for budworm in the laboratory by 12 experienced searchers from the Maine Bureau of Forestry. The same people examined the 3-day postspray samples. Seven and 14 day post-spray samples were examined on site by USDA employees because the

warm weather would have killed budworm during transport to the laboratory.

Current growth on the tip of one branch from the midcrown of each sample tree was the unit of measure used for evaluating foliage saved by treatment. The National Research Council Canada system (Appendix B) was used for this evaluation after cessation of budworm feeding.

The two PV-2 aircraft used for insecticide application were fitted with standard boom and downward - directed 8008 Tee Jet flat fan nozzles. No screens were used in the spray systems. The U. S. Forest Service Methods Application Group (MAG), State and Private Forestry, calibrated the aircraft. For a more detailed description see Table 6 on page 20.

The number of nozzles used for each insecticide were:

Orthene Forest Spray, 82.

Dylox 4, 37

Sevin 4 Oil, 37

Two percent of the Dylox 4 and Sevin 4 Oil formulations were Automate B Red Dye, and two percent of the Orthene Forest Spray formulation was Rhodamine B Extra S Dye. These red dyes were used to stain spray

deposit cards for evaluation purposes (Appendix A). The components and cost of each insecticide are shown in Table 1.

Presque Isle airport was the base of operations for the aerial phase of the project, and Oxbow Lodge, Oxbow, ME was the project headquarters (Figure 1).

Six prespray flights, totalling about 112 hours, were needed to orient pilots, to evaluate accessibility of the spray blocks, and to take 35 mm (1.4 inch) photographs.

Spraying was done on June 3 and 4 when 73 percent of the budworm larvae were in the fourth instar. One PV-2 applied the Orthene Forest Spray on the evening of June 3. The second PV-2 applied the Dylox 4 on June 3, and on June 4, applied the Sevin 4 Oil.

Observers stationed near the spray blocks recorded air temperatures, air movements, and leaf surface moisture.

RESULTS AND DISCUSSION

SURVIVAL

Two days before spray application, there was an average of about five budworm larvae on a 15-inch sample branch. At 14 days after spraying,

The average dropped to 2.5 larvae per 15-inch branch (Table 2). For each of the sampling dates, there was no significant difference in budworm populations between treatments according to an analysis of variance and F test (p=.05). The variation between replicates was so large that differences due to treatment could not be detected at 3, 7, or 14 days after spraying. Convariance analysis showed that survival of budworm in check blocks was significantly greater than in treated blocks, and that Orthene Forest Spray treatment reduced the number of budworm by a larger amount than either Dylox 4 or Sevin 4 Oil. There was no significant difference between Dylox 4 and Sevin 4 Oil treatments in terms of budworm survival.

Budworm populations on check blocks were virtually unchanged during the sampling period; but on blocks treated with insecticide, budworm populations decreased. It is assumed that the number of budworm did not change during the time between prespray sampling and spray applications. Orthene Forest Spray reduced budworm populations within three days, Dylox 4 was also effective during that time, but Sevin 4 Oil reduced budworm populations more slowly (Figure 2).

MORTALITY

During the 16-day period between prespray sampling and the last postspray sampling, budworm populations in the check blocks declined only 2.3 percent. Because of this light natural mortality, the percentage of mortality calculated by covariance and Abbott's adjustment are about the same as those without adjustment. The unadjusted budworm mortality was about 94 percent on blocks treated with Orthene Forest Spray compared to mortality levels of about 49 percent on Sevin 4 Oil blocks and about 34 percent for Dylox 4 (Table 3).

DEFOLIATION

Sample trees in the check blocks, with a budworm population of nearly five budworm on a branch sample, were defoliated only about 50 percent. Insecticide treatment could therefore save no more than half the new foliage of the sample trees. Orthene Forest Spray saved about 34 percent of the new foliage - only about 14 percent of the new foliage had been destroyed. Sevin 4 Oil prevented defoliation of about 17 percent of the new foliage, and Dylox 4 saved about 9 percent (Table 4). There was no current defoliation of old foliage (backfeeding) because new foliage, the primary food supply for budworm, was plentiful in relation to the number of larvae.

There was considerable variation in defoliation levels between clusters of sample trees. Some clusters treated with Dylox 4, for example, were 65 percent defoliated while other clusters were only 15 percent defoliated. About 44 percent of the 45 clusters in the check blocks were in the 41-60 percent defoliation class. Without insecticide treatment, clusters in all blocks would have about 44 percent of the trees in the 41-60 percent defoliation class. However, only 4 percent of the clusters treated with Orthene Forest Spray were defoliated to that degree; and no clusters received more than 60 percent defoliation. Dylox 4 and Sevin 4 Oil treatments reduced the number of clusters expected to be moderately defoliated, but did not prevent heavy defoliation of some clusters (Table 5).

A Chi-square test (p=.05) indicates that the distribution of numbers of clusters in defoliation classes is different between treatments. Of the total Chi-square value (59.27), most is attributable to the frequent occurrence of clusters in the Orthene Forest Spray, 0-20 percent defoliation class. Since only a minor amount of Chi-square is attributable to the difference in heavy defoliation classes between check, Dylox 4, and Sevin 4 Oil treatments, it seems that these treatments did not prevent some clusters from being heavily defoliated.

INSECTICIDE APPLICATION

The Dylox 4 application of 12.5 ounces an acre was less than planned because pump pressure was variable and a solvent in the formula cleaned scale from the spray tank. This loosened scale plugged the nozzles which should have been fitted with 50 mesh screens. There should have been 46 instead of 37 nozzles on the boom. The Sevin 4 Oil application was erratic with several missed swaths and some overlapped swaths because of poor coordination between the spray plane and the guide plane. The Orthene application was reduced to 2500 acres because there was an insufficient supply of insecticide (Table 6). However, all plots originally established were sprayed as planned.

The following is a summary of spraying sequence and weather conditions:

	Forest Orthene Spray	Dylox 4	Sevin 4 Oil
Date	June 3	June 3	June 4
Hour: Start	1955	0645	0900
End	2045	0810	1010
Wind (mph)	0-3	0-2	2-4;8
Temperature (^{o}F)	58-54	44-48	69-71
Leaf surface	moist	dry	dry

During the application of Sevin 4 Oil, the warm air temperatures prevented the rapid settlement of some spray droplets.

The catch of Arthropods on drop cloths gave an indication of the relative impact of the several treatments. In relation to Orthene Forest Spray and Dylox 4, Sevin 4 Oil had little impact on non-target Arthropods. Dylox 4 killed a relatively high number of beetles and flies in comparison to the other insecticides. In proportion to the number of budworm found on the cloths, Orthene Forest Spray had less impact than Dylox 4 on non-target Arthropods; and the impact of Orthene Forest Spray and Sevin 4 Oil on non-target Arthropods were about equal. A summary of the drop cloth catch is:

Number of Individuals Killed

Classification	Orthene Forest Spray	Dylox 4	Sevin 4 Oil
Moths (except budworm)	9	3	3
Beetles	37	52	20
Wasps, Bees	15	9	5
Bugs	20	7	7
Flies	95	121	40
Spiders	17	6	6
Spruce budworm	693	230	282
Other[a/]	3	3	5

a/ Includes: Mayflies, grasshoppers, leaf hopper, centipede, thrips, and caddisflies.

CONCLUSIONS

Under conditions of this project, we conclude that:

1. Orthene Forest Spray, applied at 8 ounces active acephate in water to make 64 ounces/acre was effective in saving balsam fir foliage from spruce budworm defoliation, and in reducing budworm populations.

2. Dylox 4, applied at 4.1 ounces active trichlorfon in Hi-Sol 4,5T to make 12.5 ounces/acre was of insufficient volume and dosage to effectively save foliage or reduce budworm populations.

3. Sevin 4 Oil, sprayed at 10.8 ounces active carbaryl in kerosene to make 27 ounces an acre more or less, was applied under such marginal conditions that we could not determine efficacy of the formulation.

4. As shown in the check blocks, there is no need to use insecticides to prevent heavy defoliation if there are fewer than 5 third instar budworm/15-inch balsam fir branch tip.

ACKNOWLEDGEMENTS

This project would not have been completed without the cooperation and assistance of numerous people. Their efforts, made in either the field or office, contributed substantially to the project. Though thanks are given to all those involved, appreciation is extended to the following people in particular:

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Globe Air for the spray aircraft.

Northern Maine Vocational Technical Institute which provided dining facilities.

Table 1.-- Amount and cost of insecticide formulations, Spruce Budworm Pilot Control Project, Maine, 1976.

MATERIAL	AMOUNT USED	TOTAL COST
Sevin 4 Oil	955 ga	$ 8,840.70
Kerosene	293 ga	293.00
Automate B Red Dye	25 ga	46.50
Dylox 4	972 ga	$10,935.00
Hi-Sol 4,5T	297 ga	307.80
Automate B Red Dye	27 ga	50.22
Orthene Forest Spray	2,500 lbs	$13,000.00
Rhodamine B Extra S Dye	12 lbs	1,022.80

Table 2.-- Number of spruce budworm larvae/15-inch branch in relation to time of treatment with insecticides, Spruce Budworm Pilot Control Project, Maine, 1976.

INSECTICIDE	BLOCK NO.	2 DAYS PRESPRAY (Av. No. Larvae)	14 DAYS POSTSPRAY (Av. No. Larvae)
Orthene Forest Spray	2	2.13	0.18
	9	9.07	0.62
	11	5.42	0.22
	Mean	5.54	0.34
Dylox 4	3	2.34	1.78
	6	7.72	4.50
	7	3.55	2.81
	Mean	4.57	3.03
Sevin 4 Oil	1	1.68	0.92
	5	3.29	2.21
	10	6.91	2.87
	Mean	3.96	2.00
Check	4	2.55	2.37
	8	10.03	7.87
	12	1.95	3.96
	Mean	4.84	4.73

Table 3.-- Budworm mortality at 14 days postspray, Spruce Budworm Pilot Control Project, Maine, 1976

(In Percent)

Insecticide Treatment	Mortality Calculation		
	Unadjusted	Covariance Adjustment	Abbott's Adjustment
Orthene Forest Spray	93.8	99.7	93.7
Dylox 4	33.7	33.9	32.1
Sevin 4 Oil	49.4	50.7	48.2
Check	2.3	-	-

Table 4.-- Defoliation estimates and Foliage saved by treatment, Spruce Budworm Pilot Control Project, Maine, 1976 (In Percent)

Treatment	Defoliation	Foliage Saved
Orthene Forest Spray	14	34
Dylox 4	39	9
Sevin 4 Oil	31	17
Check	48	-

Table 5.-- Number of balsam fir clusters in defoliation classes by treatment, Spruce Budworm Pilot Control Project, Maine, 1976.

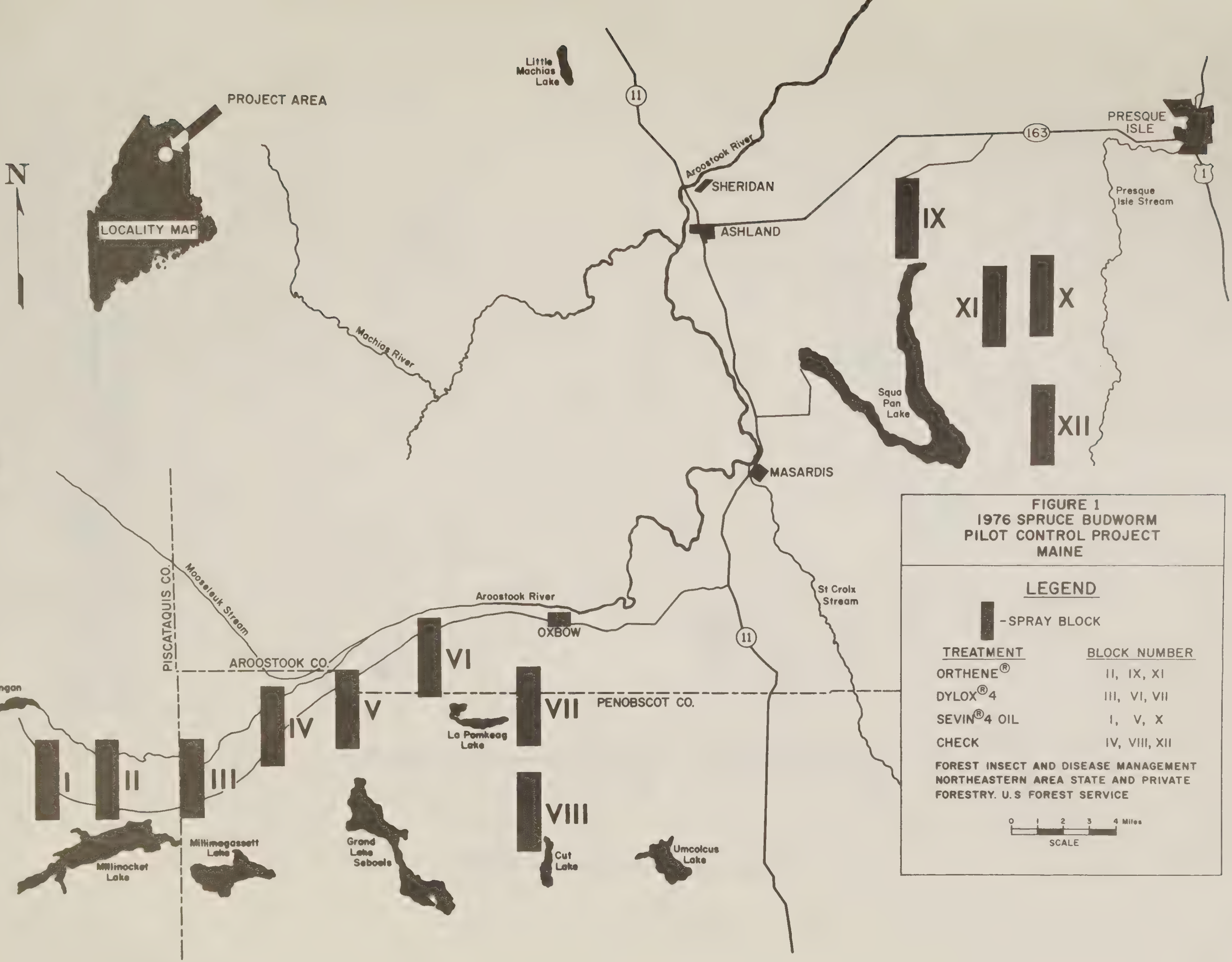
Percent Defoliation Class	Number of Clusters in Treatment			
	Orthene Forest Spray	Dylox 4	Sevin 4 Oil	Check[b/]
0-20	34	13	20	3
21-40	9	14	10	14
41-60	2	9	10	20
61-80	0	6	4	6
81-99	0	3	1	2
Total	45	45	45	45

[b/] Between treatment Chi-square, P=.05, 59.27

Table value of Chi-square, 12 d.f., 21.0

Table 6.-- Statistics and values for items used, Spruce Budworm Pilot Control Project, Maine, 1976.

Item	Insecticides: Orthene Forest Spray	Dylox 4	Sevin 4 Oil
Aircraft	PV-2	PV-2	PV-2
Identification	N6588C	N7268C	N7268C
Pilot	Mangles	Wilkins	Wilkins
Air Speed (mph)	175	175	175
Nozzle Size	8008	8008	8008
No. of Nozzles	82	37	37
Boom Pressure (psi)	40	30-40	40
Swath Width (ft)	365	365	365
Spraying Altitude (ft)	100-150	100-150	100-150
Acres Treated	2500	4800	4800
Application Rate/A (oz)	64	12.5	27
Dosage Rate/A (oz)	8	4.1	10.8



PROJECT AREA
LOCALITY MAP
N
Little Machias Lake
Machias River
Aroostook River
SHERIDAN
ASHLAND
11
163
PRESQUE ISLE
1
Presque Isle Stream
IX
X
XI
XII
Squa Pan Lake
MASARDIS
St Croix Stream
PISCATAQUIS CO.
Mooseleuk Stream
OXBOW
AROOSTOOK CO.
PENOBSCOT CO.
Munsungan Lake
I
II
III
IV
V
VI
VII
VIII
La Pomkeag Lake
Millimocket Lake
Millimagassett Lake
Grand Lake Seboeis
Cut Lake
Umcolcus Lake
FIGURE 1
1976 SPRUCE BUDWORM
PILOT CONTROL PROJECT
MAINE
LEGEND
-SPRAY BLOCK
TREATMENT — BLOCK NUMBER
ORTHENE® — II, IX, XI
DYLOX®4 — III, VI, VII
SEVIN®4 OIL — I, V, X
CHECK — IV, VIII, XII
FOREST INSECT AND DISEASE MANAGEMENT
NORTHEASTERN AREA STATE AND PRIVATE
FORESTRY. U.S FOREST SERVICE
0 1 2 3 4 Miles
SCALE

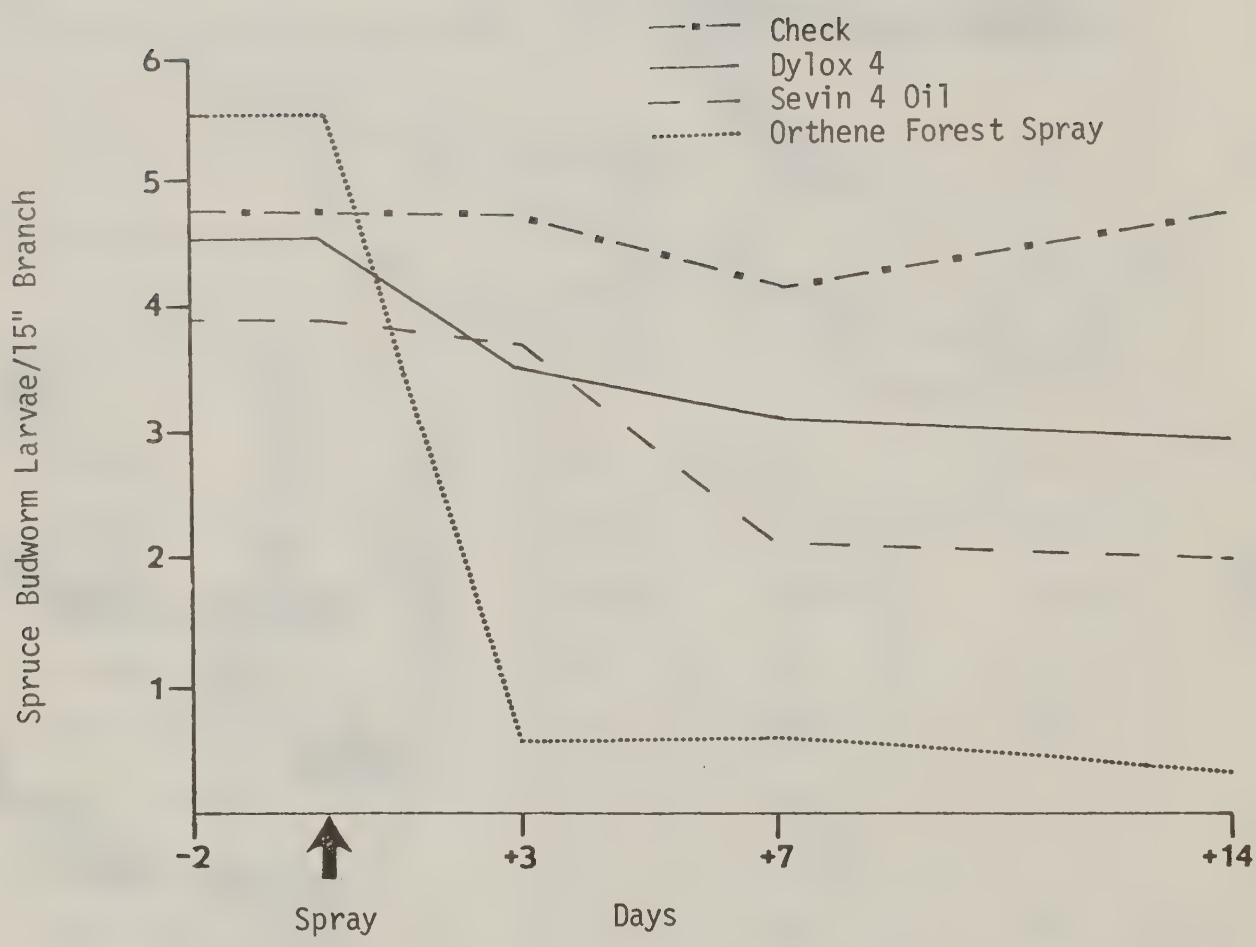


Figure 2. -- Number of budworm larvae/15-inch branch in relation to time of treatment. Spruce budworm pilot control project, Maine, 1976.

APPENDIX A

SPRAY DEPOSIT ANALYSIS

INTRODUCTION

In the pilot control project to determine efficacy of Orthene Forest Spray, Dylox 4, and Sevin 4 Oil against spruce budworm in Maine, we use Kromekote(R) cards to measure spray deposit. This appendix describes methods, analyses, and results of our spray deposit monitoring.

The plans and methods were suggested by Jack Barry, Pilot Project Specialist, Methods Application Group, U.S.D.A. - Forest Service, Davis, CA. Most of the analyses were done by MAG. Interpretations and conclusions drawn from the analyses are by Robert P. Ford.

METHODS AND MATERIALS

White Kromekote spray deposit cards, 4 inches by 5 inches, held flat by plastic holders, provided the basis for all spray deposit work.

One hour before each block was sprayed, spray deposit cards were placed at the dripline of each sample tree. The cards were placed at cardinal directions. Since there were 45 trees in each of three replicates, there were 540 cards available for analysis for each treatment and unsprayed check block. Cards at the dripline were classified

as "under trees". In each block we put a row of spray deposit cards along the center of a haul road or other large opening so that they were about 20 feet to 180 feet away from any tree. These cards, classified as "in open", were about 100 feet apart and arranged so they covered several spray swaths and related to the cards under trees. Each row consisted of 25 cards.

Each card was placed so that it was level. In some cases card holders were placed on boulders, stumps, or fallen trees instead of directly on the ground. It was necessary to remove small trees, brush, and undergrowth so that only the sample tree was above the card. This was done so that nothing obstructed the fall of a drop except the sample tree and the spray deposit card. Cards, in the plastic holders, were carried in wooden tote boxes to protect them from dirt and abrasion. A box held 60 cards - enough to monitor 15 trees.

A ball-point pen was used to mark identification codes on the narrow margin of each card. The codes, in order, were: block, cluster, tree, and cardinal direction. For example: Block 10, cluster 2, tree C, on the east side

became

10 - 2 - 3 - 2

where

north was 1, east 2, south 3, and west 4.

Cards in openings were coded with the block number, then labeled in sequence from an identifiable point. A map of each block showed where the cards were placed.

Cards were retrieved within four hours after spraying was completed. At headquarters, cards were taken from the tote boxes and holders, checked for coding, and packed in plastic bags. These cards were shipped to MAG to be analyzed for volume of spray and number of droplets. Most of the cards were analyzed with the Quantimet 720 Image Analyzer; but many, especially those with dirt or honeydew spots, were counted "by hand" at the MAG laboratory. The Quantimet is located at the Los Alamos Scientific Laboratory, New Mexico.

Spray deposit cards were analyzed to determine the ratio of droplets in openings to droplets under trees, the relationship of number of spray droplets and volume of spray droplets to defoliation and budworm mortality, and the proportion of spray volume that reached the target.

RESULTS AND DISCUSSION

DISTRIBUTION AND RETRIEVAL OF SPRAY DEPOSIT CARDS

The 180 cards/block were in place within 15 minutes after a crew arrived at the block. During retrieval of card, the crews found

that nearly 20 percent of those in openings had been destroyed by vehicles which had driven over them or cast dirt on them. Cards retrieved 1-4 hours after morning spraying were flat, dry, and clean; but those collected an hour after evening spraying were buckled or stuck to holders because they were wet from dew.

NUMBER OF SPRAY DROPLETS

Although the aircrafts were calibrated to produce 20 droplets/cm^2 within the effective swath width, the number of droplets found on cards in openings was considerably less (Table 1). Twice as many droplets impinged on cards in openings as on cards under trees, which indicated that about half the droplets that approached the tree canopy were intercepted. These droplets contained the insecticide available to the target insect.

Canopy penetration curves developed by MAG show that the ratio of droplets under trees to droplets in openings decreased as droplet size increased, indicating that large droplets were intercepted by trees (Figure 1 to 3).

As the number of spray droplets/cm^2 increased, the percentage of budworm mortality increased - but at different rates for each insecticide. Sevin 4 Oil showed the greatest rate of increase in budworm mortality and Dylox 4 the lowest (Figure 4). The curves were fitted by ocular

estimate from scatter diagrams provided by MAG. The set of curves indicates that if he had wanted to kill 90 percent of the budworms, the following minimum number of droplets would have to be found on spray deposit cards under trees:

Orthene Forest Spray	8 droplets/cm^2
Dylox 4	11 droplets/cm^2
Sevin 4 Oil	7 droplets/cm^2

The curve for Orthene Forest Spray was difficult to fit because the scatter diagram showed no clear curve. As a result, the number of droplets (8) from the curve is more than enough to produce 90 percent budworm mortality if comparison is made with the actual number of droplets (7) needed to attain 93 percent mortality in this project (Table 1).

Another set of curves was constructed to show the relationship of the number of droplets under trees to the percentage of defoliation (Figure 5). Sevin 4 Oil provided foliage protection when only a small number of droplets were deposited because the toxicity is persistent, but a large number of droplets of Dylox 4 was needed to attain this same degree of foliage protection. The Orthene Forest Spray curve was difficult to construct because there was wide variation in the defoliation - number of droplets relationship. The curves indicate that at least six droplets/cm^2 on cards under trees is required if we are to be reasonably sure foliage protection will be more than 80 percent. Since very few cards had less than 6 drops, the data for larval doses is weak.

VOLUME OF SPRAY DROPLETS

Volume of spray droplets (mass) was measured by MAG in ounces/acre of formulation which settled on spray deposit cards set under sample trees and in openings. The volume median diameter of spray droplets was less under trees than in openings, but was of satisfactory magnitude in all cases (Table 1).

The volume of insecticide recovered on spray deposit cards was a small percentage of the volume sprayed from the aircraft (Table 2). Normally, about 30 to 40 percent of the emitted spray would be deposited on cards in openings. Orthene Forest Spray met this expectation, but Dylox 4 and Sevin 4 Oil did not. Probably, much of the alcohol base of the Dylox 4 evaporated during droplet descent so that deposited droplets were small. Sevin 4 Oil, in an oil base, was recovered in suitable droplet size but in low proportion to emitted volume because the application was not as uniform as it should have been.

A small volume of insecticide penetrated the tree canopy and was collected on cards (Table 2). The difference in volume between under trees and in openings represents the volume intercepted by trees. This amount of insecticide, available to kill budworm, was:

Orthene Forest Spray	17.9 ounces/acre
Dylox 4	1.5 ounces/acre
Sevin 4 Oil	4.9 ounces/acre

The volume of insecticide found on cards under trees, when increased by a very small amount, caused a large increase in budworm mortality (Figure 6).

Dylox 4 showed the most dramatic increase; and Orthene Forest Spray showed a gradual increase in budworm mortality as mass (volume) of insecticide impinging on cards increased. The graph in Figure 6 indicates that for 90 percent reduction in budworm population, the following volume of insecticide should be deposited on cards under trees:

Orthene Forest Spray	8.5 ounces/acre
Dylox 4	4 ounces/acre
Sevin 4 Oil	5 ounces/acre

These values, when compared with those we got - 11.56 ounces/acre of Orthene Forest Spray, 1.26 ounces/acre of Dylox 4, and 2.1 ounces/acre of Sevin 4 Oil - showed that we needed to increase the volume of Dylox 4 and Sevin 4 Oil, but could probably have reduced the volume of Orthene Forest Spray.

A small increase in the volume of Dylox 4 on the spray deposit cards under trees produced a large decrease in the amount of defoliation caused by budworm (Figure 7). More than 9 ounces/acre of Dylox 4 or less than 7 ounces/acre were not found on the spray deposit cards under

trees. Under conditions of this project, 2 ounces/acre of Dylox 4 or 4 ounces of Sevin 4 Oil deposited on cards under trees would have kept defoliation levels at less than 20 percent (Figure 7). Also, a recovery of 7 ounces/acre of Orthene Forest Spray on cards under tree would signify no more than 20 percent defoliation. These speculative values, when compared to the volumes attained on the Project - 11.56 ounces/acre of Orthene Forest Spray, 1.26 ounces/acre of Dylox 4, and 2.1 ounces/acre of Sevin 4 Oil - indicate that we could have used a smaller volume of Orthene Forest Spray; but we should have increased the volumes of Dylox 4 and Sevin 4 Oil. To sensitize the analysis further more cards would have been required.

CONCLUSIONS

From the analyses of spray droplet data it is concluded that:

1. The planned droplet size was achieved.
2. Where spray volumes and densities were satisfactory, all three insecticides were equally effective in preventing defoliation and in reducing budworm populations.
3. The larger droplets were intercepted by trees in greater proportion than smaller droplets.

Table 1.-- Spray droplet numbers and volume median diameter recovery, Spruce Budworm Project, Maine, 1976.

Insecticide	VMD (um)		Droplets/cm^2	
	Under Trees	In Open	Under Trees	In Open
Orthene Forest Spray	160	167	7	15
Dylox 4	90	96	6	12
Sevin 4 Oil	136	139	4	10

Table 2.-- Spray recovery in volume and percent of insecticide applied/acre, Spruce Budworm Project, Maine, 1976

Insecticide	Emitted Rate	Recovery Under Trees		Recovery In Openings	
	oz/A	oz/A	Percent	oz/A	Percent
Orthene Forest Spray	64	11.56	18	29.49	46
Dylox 4	12.5	1.26	10	2.74	22
Sevin 4 Oil	27	2.10	8	7.00	26

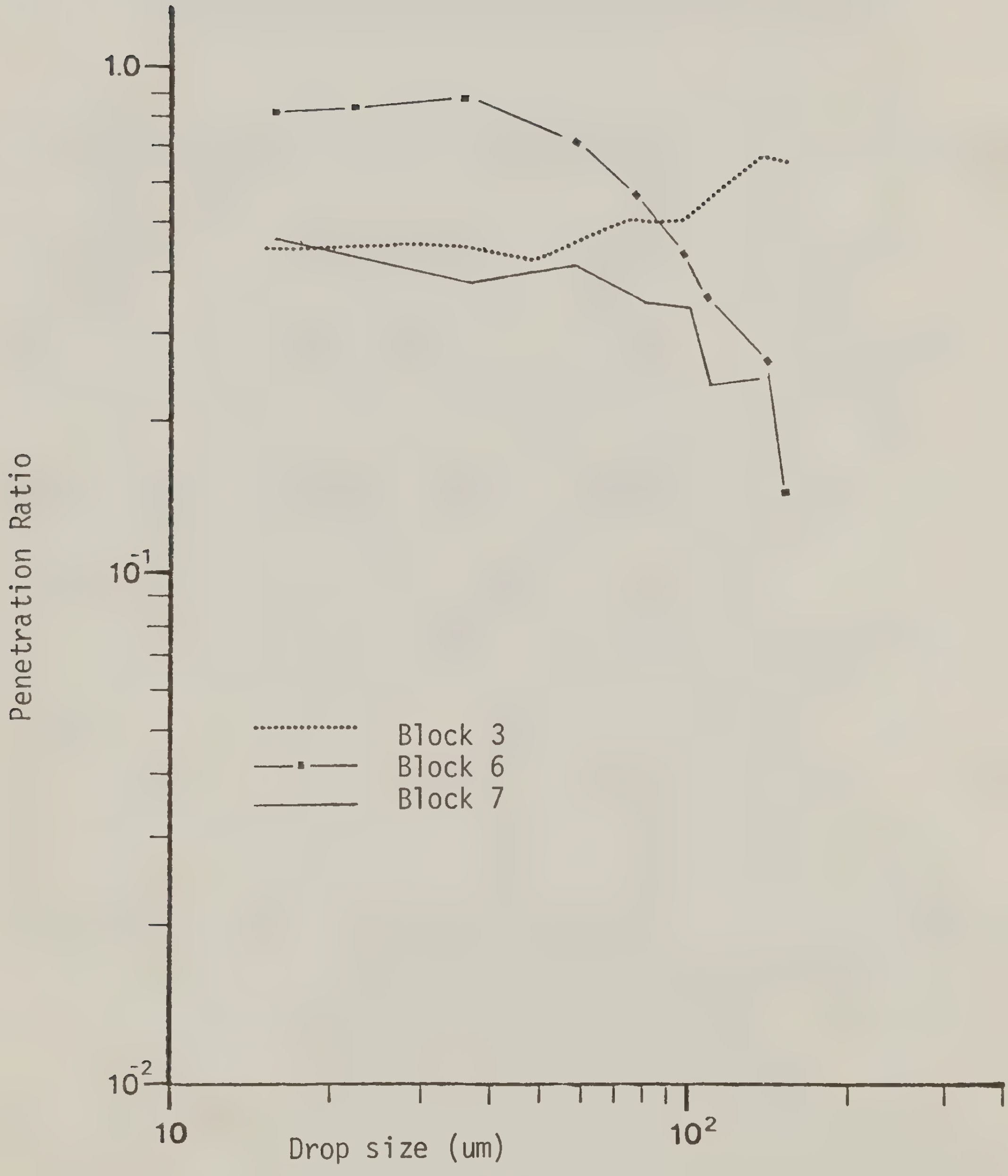


Figure 1. -- Canopy penetration, Dylox 4, spruce budworm pilot control project, Maine, 1976. Penetration ratio is drops under trees to drops in open as a function of drop size.

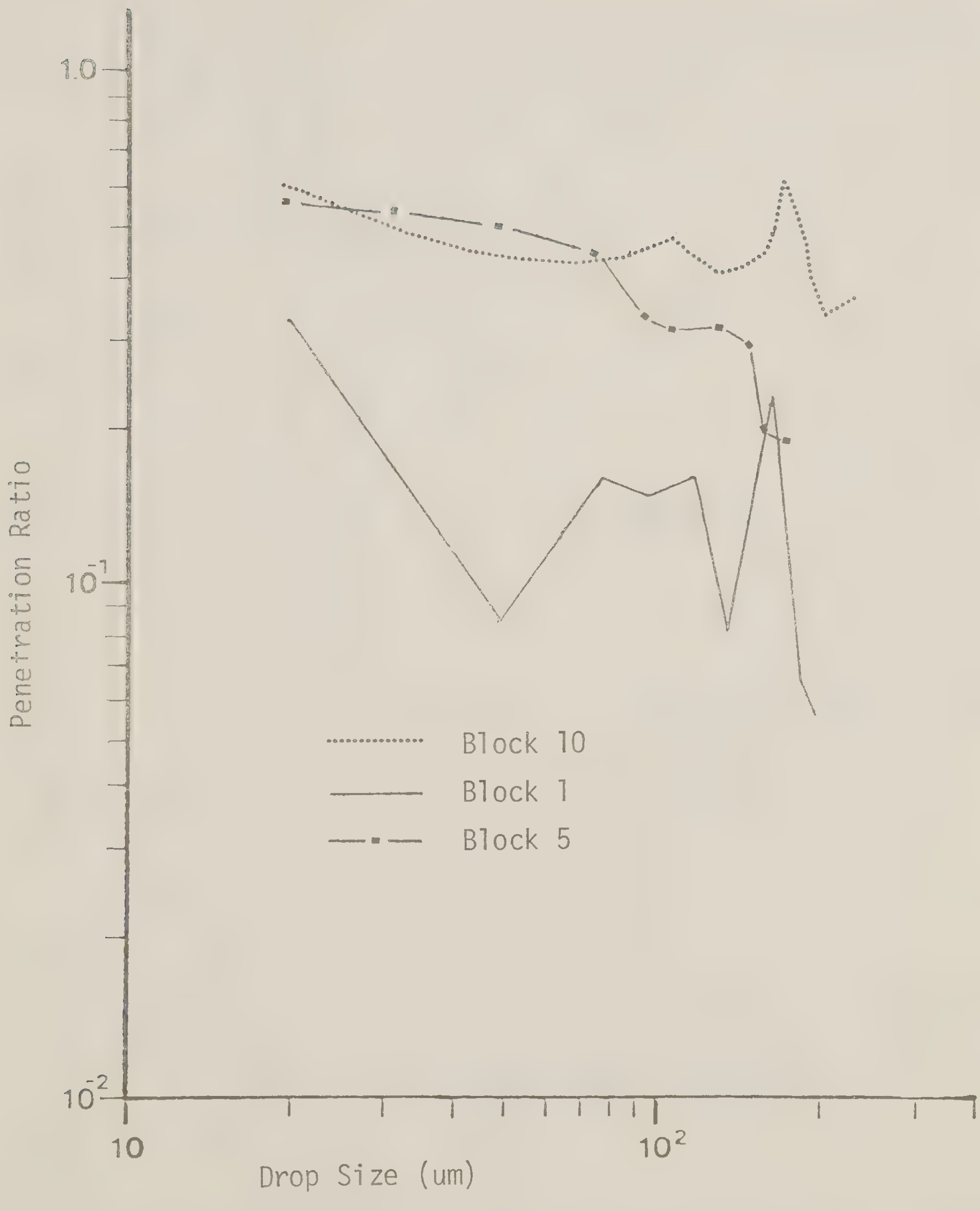


Figure 2. -- Canopy penetration, Sevin 4 Oil, spruce budworm pilot control project, Maine, 1976. Penetration ratio is drops under trees to drops in open as a function of drop size.

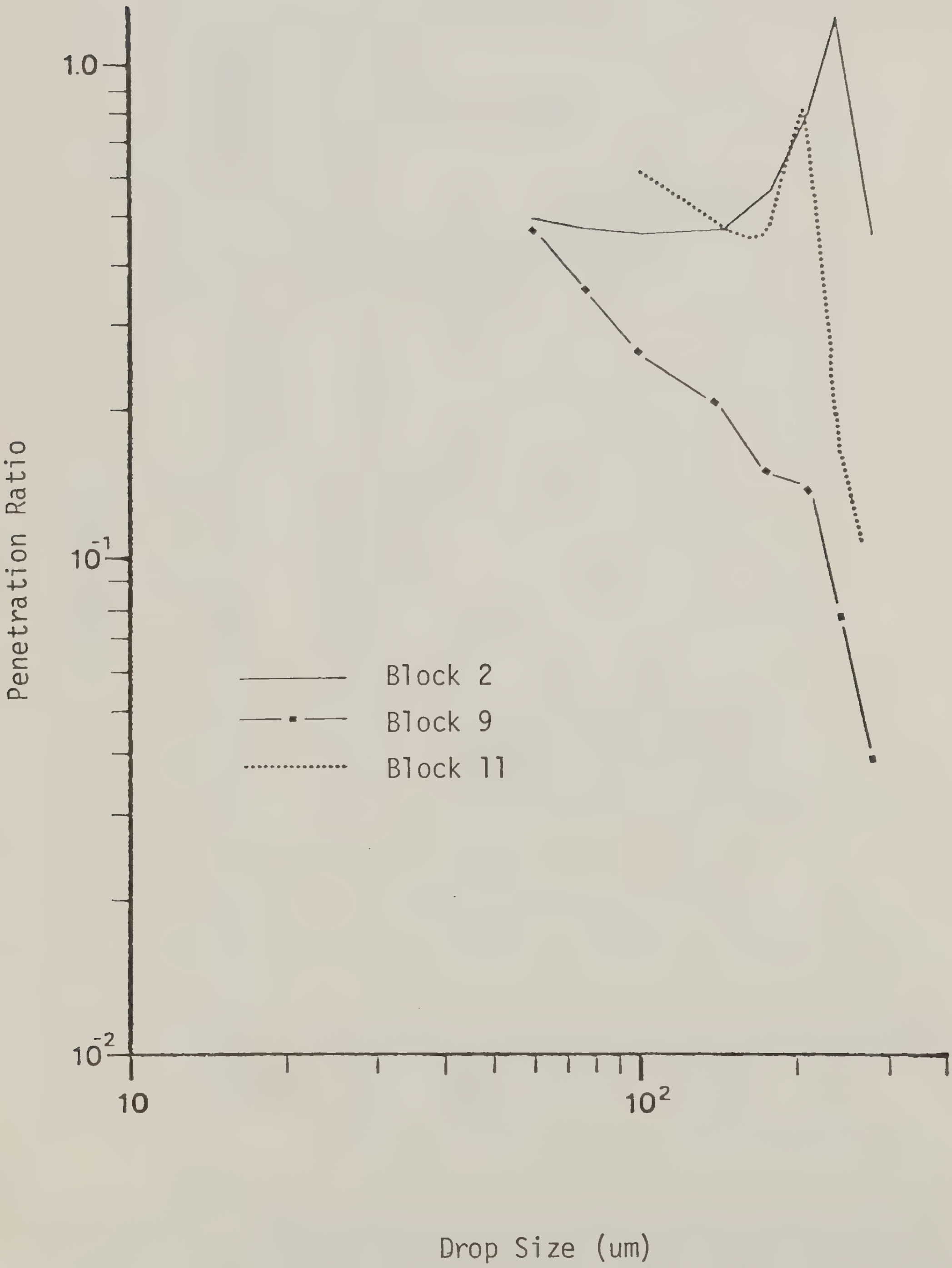


Figure 3. -- Canopy penetration, Orthene Forest Spray, spruce budworm pilot control project, Maine, 1976. Penetration ratio is drops under trees to drops in open as a function of drop size.

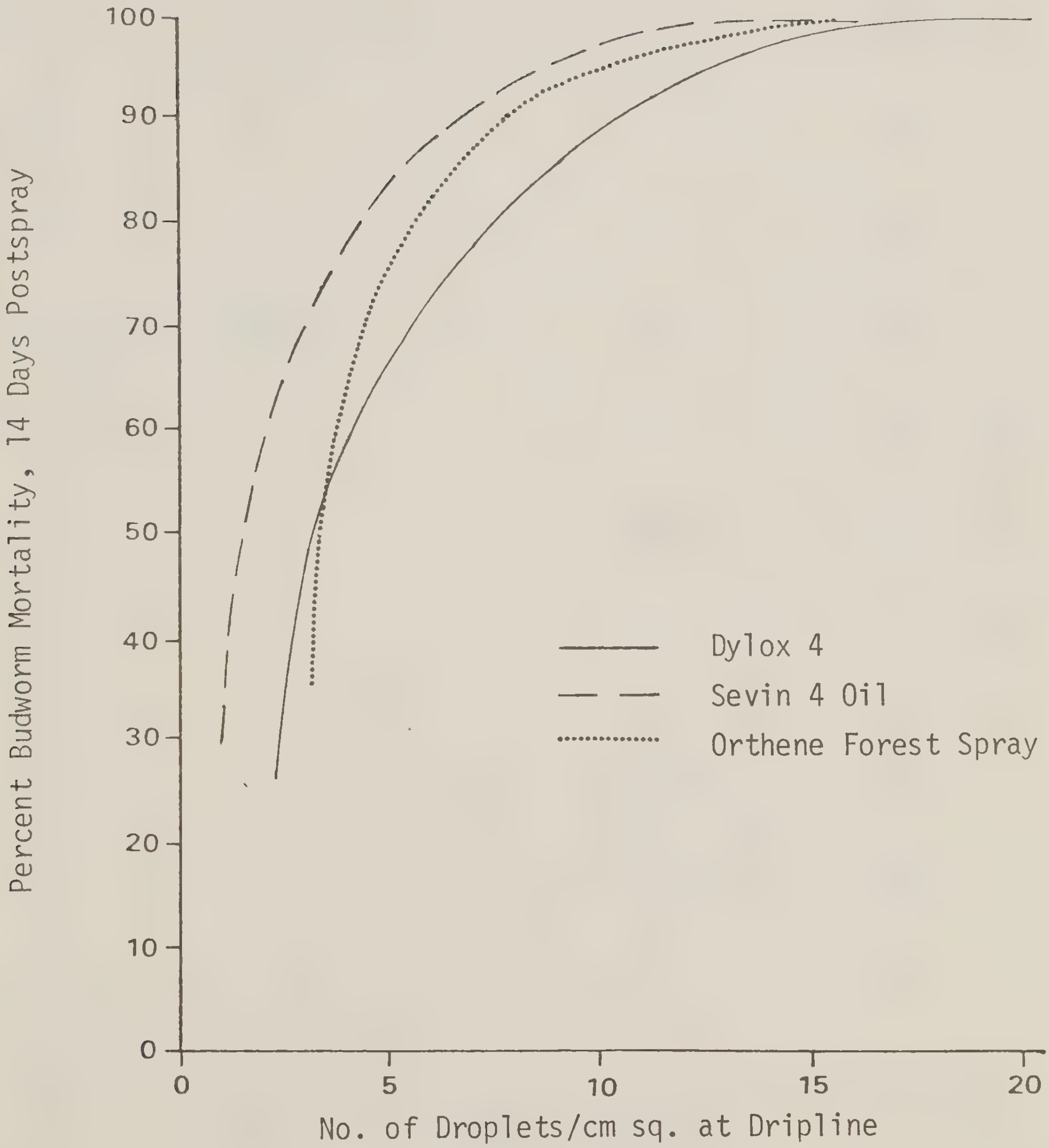


Figure 4. -- Relationship of number of droplets/cm sq. to percent budworm mortality for several insecticides. Spruce budworm pilot project, Maine, 1976.

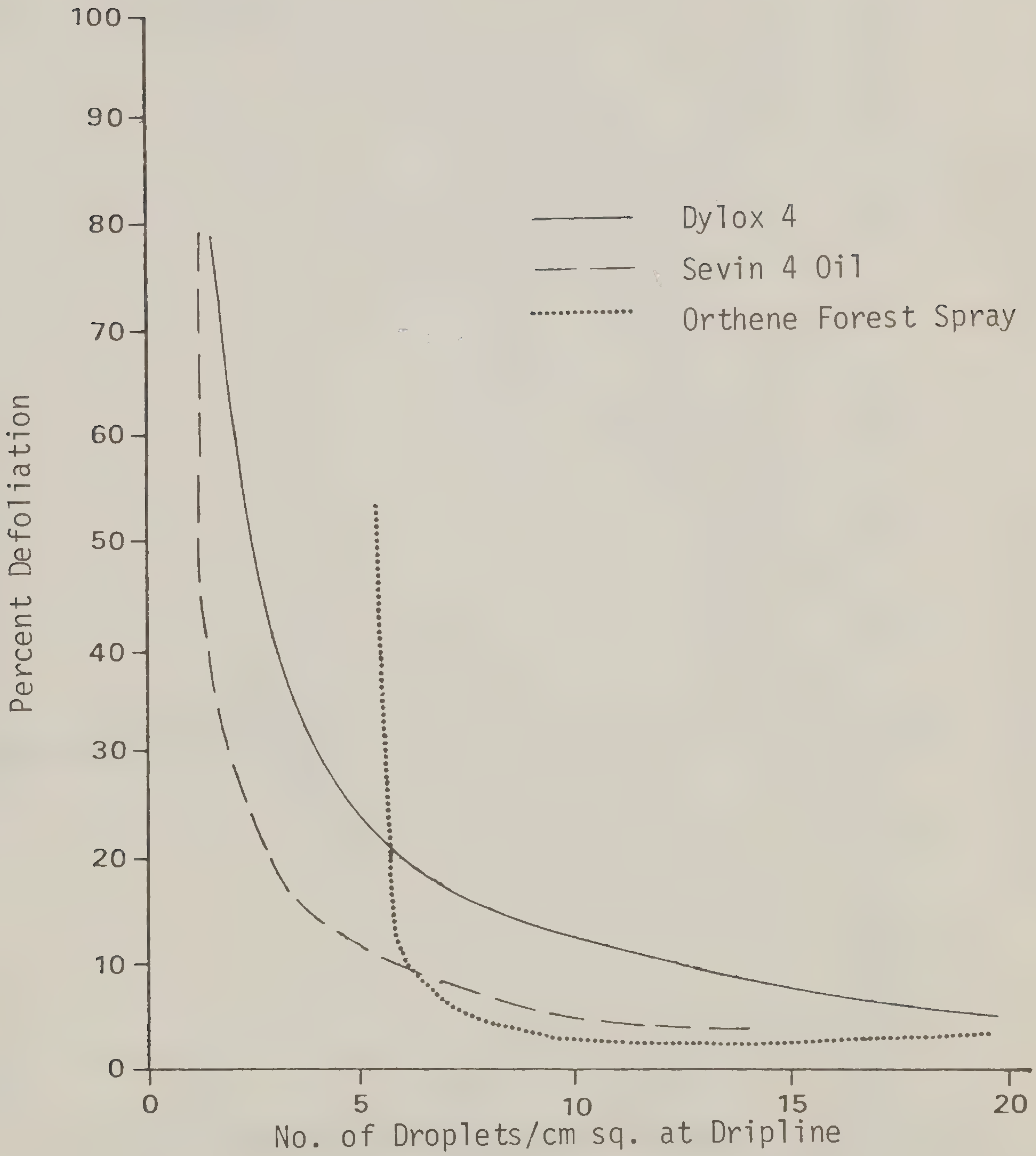


Figure 5. -- Relationship of number of droplets/cm sq. to percent defoliation of three-tree clusters for several insecticides. Spruce budworm pilot control project, Maine, 1976.

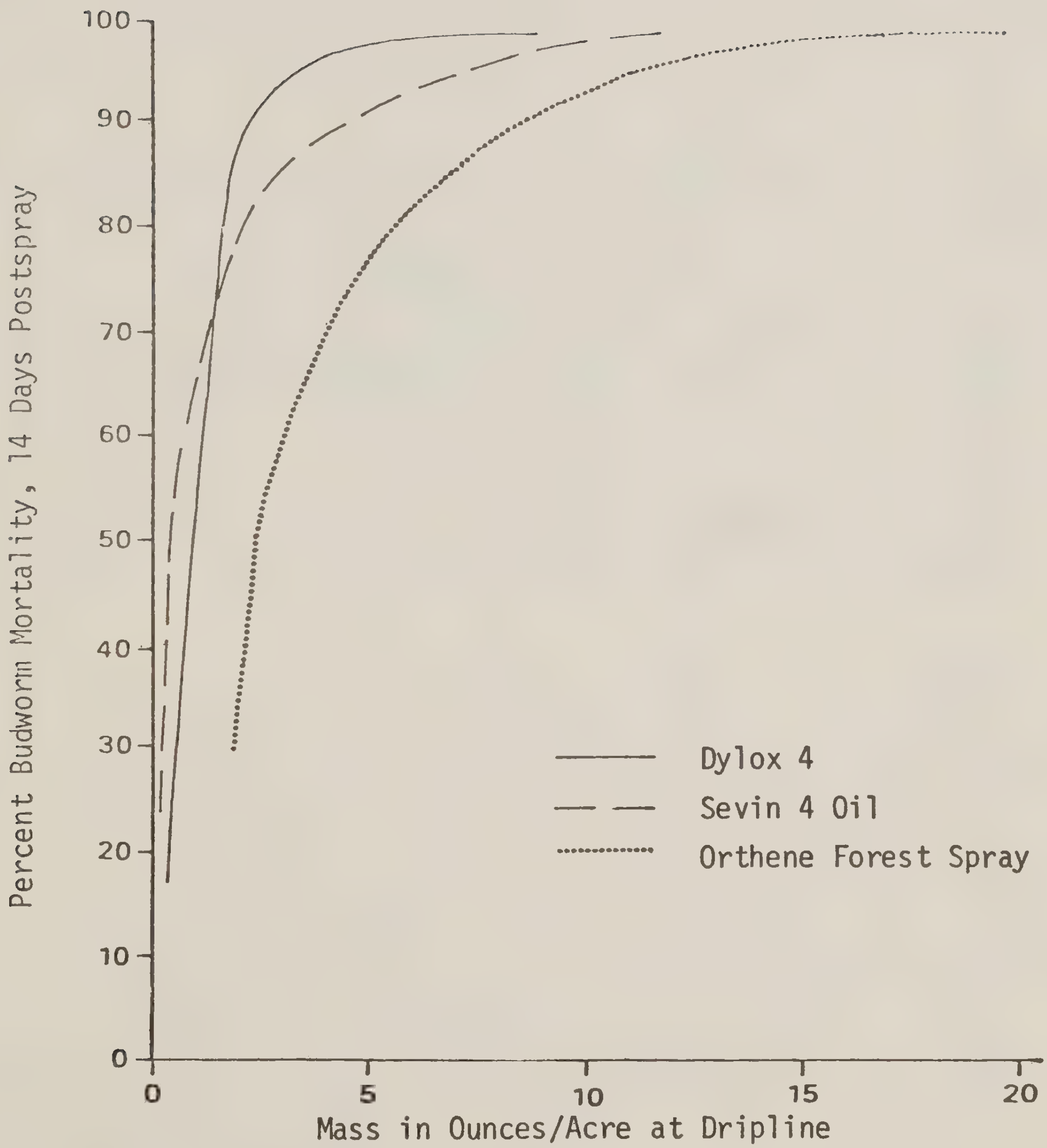


Figure 6. -- Relationship of mass (ounces/acre) to percent budworm mortality for several insecticides. Spruce budworm pilot control project, Maine, 1976.

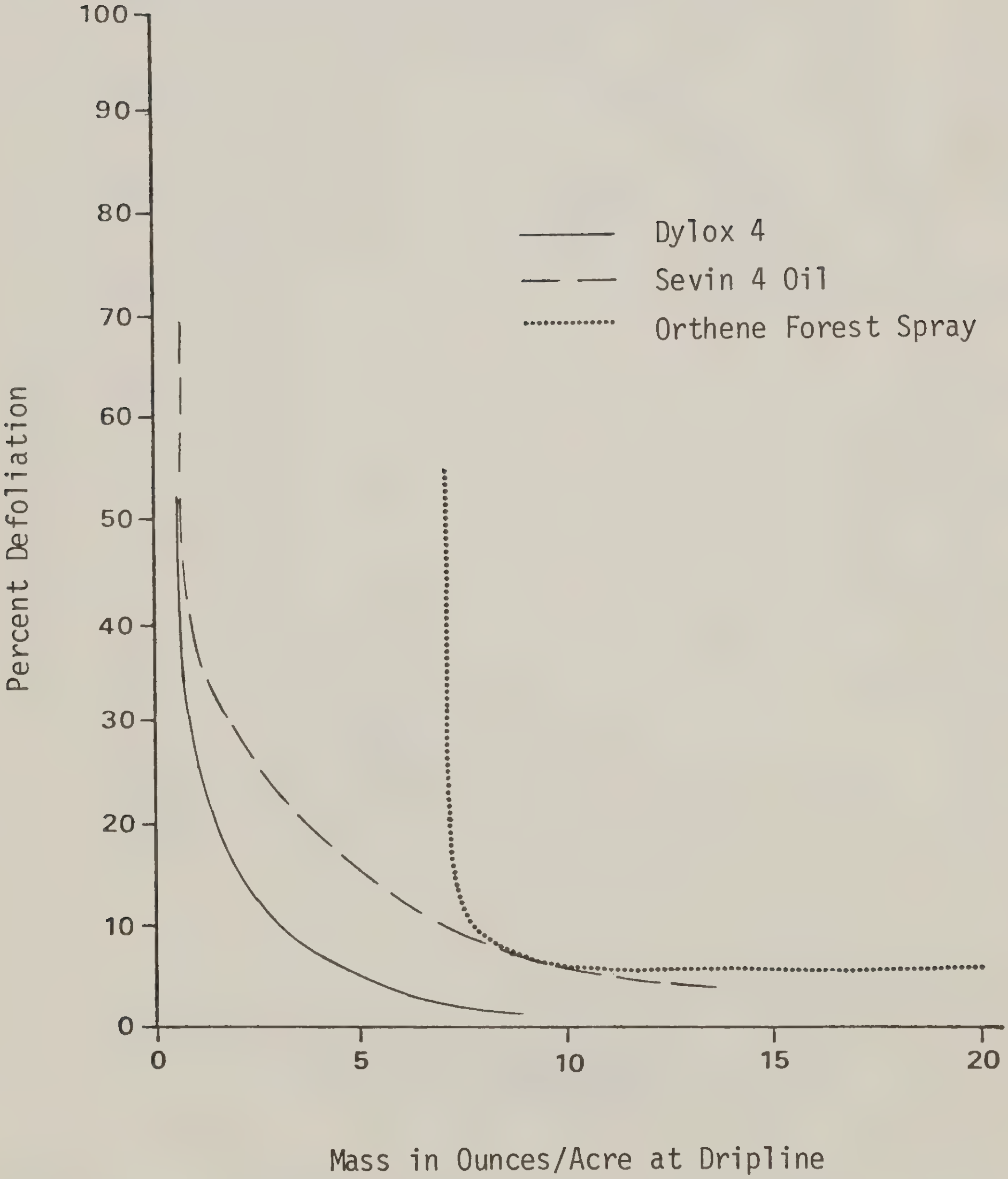


Figure 7. -- Relationship of Mass (ounces/acre) to percent defoliation of three-tree clusters for several insecticides. Spruce budworm pilot control project, Maine, 1976.

APPENDIX B

Comparison of Canadian Tree Vitality Index with the Conventional Method

INTRODUCTION

Defoliation of balsam fir (Abies balsamea (L.) Mill.) by spruce budworm (Choristoneura fumiferana (Clem.)) reduces the amount of photosynthate a tree can produce. New foliage is the major source of food for the budworm which begins its attack by feeding on buds then by eating newly expanded needles. When more than 65 percent of new foliage is eaten by budworm, the tree loses vigor; and after three successive years of such defoliation the tree loses vitality.

Vitality of a tree can be estimated by comparing the amount of foliage and number of buds on the tree with those of a healthy tree. The National Research Council Canada (NRCC) developed a procedure for estimating a vitality index for balsam fir (Dorais and Hardy, 1976). This system was intended for use on extensive stands of balsam fir to evaluate efficacy of a spray project. We used the NRCC system in this project for the same purpose, and compared it with the conventional method for estimating defoliation.

The conventional method provides a subjective evaluation of current foliage loss only. It does not include an estimate of tree vitality.

This Appendix reports on our comparison of the two systems, and the application of the NRCC system for determining tree vitality indicies. A decrease in the vitality index means tree health is improving. A tree with a full complement of buds and new foliage would have a vitality index of zero, and a tree with an index of 100 would be dead.

METHODS

Twelve blocks of 1600 acres each were selected in the spruce-fir region of northern Maine. Within each block we marked 45 dominant balsam fir as sample trees. In May, before budworm larvae entered fir buds, we cut one 15-inch long branch tip from the midcrown of each sample tree and classified it according to the NRCC system.

In August, after budworm feeding ended, we again cut one 15-inch branch tip from each sample tree and classified it according to the NRCC system. We also cut four other branch tips from the same tree so that five branches constituted a sampling unit to estimate defoliation in the conventional manner.

The conventional method of estimating defoliation involves a subjective estimate of new foliage missing on each branch tip then averaging percentage of defoliation for the five branches. Since sample trees were in clusters of three trees, a value for percent defoliation of a cluster was the average of the three trees.

The NRCC system involved a schematic of a balsam fir branch tip consisting of three current year shoots (Figure 1). Defoliation of each shoot, to the nearest 10 percent, was recorded in code (4 meant 30 to 40 percent defoliation and 9 meant 80 to 90 percent defoliation, for example) in small boxes of the schematic (Fettes, 1950). The codes included an 11 + which meant that the terminal bud of a shoot was missing but side buds were present. A 12 value was assigned to a dead shoot (Figure 2). In calculating defoliation, the highest class we used was 10 because classes 11, 11 +, and 12 also meant 100 percent defoliation. These last values given were used in calculating tree vitality. If a shoot was missing, we put an X in the square and then used the number of shoots remaining to arrive at an average.

Branch terminals were selected at random from tree midcrowns during the prespray sampling; but in postspray sampling, a branch had to have at least one live terminal shoot so we could determine defoliation levels for 1976.

The schematic had three small circles at the end of each shoot to represent buds (Figure 1). A 1 meant that the bud was present, a 0 meant that it was absent. If a fourth bud was present, it was ignored.

A top portion of the schematic was used to record prespray information (Figure 1). The percent of buds absent and the defoliation

class converted to percent of defoliation were used to calculate a prespray vitality index for each tree, cluster, and treatment.

During the postspray evaluation, we recorded the defoliation for the current year and the previous year (Figure 1, lower circles). The previous year defoliation data from the postspray and prespray surveys were used to determine the amount of backfeeding. A higher value for defoliation postspray than prespray meant that the budworm had eaten all the current year foliage and had to go back to the old foliage to find food.

Postspray data for defoliation and presence of buds were used to calculate a postspray tree vitality index. The prespray indices were compared to the postspray indices by a _t_ test (P = .05) to detect differences. The index was calculated by multiplying the percentage buds absent by three, adding the percent of defoliation, and dividing the result by four. The value for backfeeding was added to arrive at the index. If the backfeeding value was zero or negative, it was not added in the calculations (Figure 1).

The postspray defoliation classes were averaged for each cluster, then converted to percentage defoliation. These percentages were compared by _t_ test (P = .05) to the conventional method percentages.

RESULTS

The mean values for tree vitality before spraying were about equal among check, Sevin 4 Oil, and Orthene Forest Spray treatments; but was lower for the Dylox 4 treatment (Table 1).

There was no backfeeding in any block probably because larvae had sufficient new foliage to eat. Old foliage is eaten (backfeeding) only after new foliage has been destroyed.

For the four treatments there was a big difference between postspray and prespray vitality indices (Figure 3). In this figure Orthene Forest Spray exhibits the best vitality index. The trees improved in all but one block, a Dylox 4 treatment in which the vitality index did not change (Table 1). The difference between pre- and postspray vitality indices was highly significant.

The average defoliation for all 180 clusters, as estimated by the conventional method, was 36 percent; and by the NRCC system it was 33 percent (Table 1). These means did not differ either biologically or statistically.

DISCUSSION

The surveyors thought the conventional method for estimating defoliation was more rapid than the NRCC system because they did not need reference

to Figure 2 and did not have to use special forms. It took less time to cut and look at five branches than to cut and examine three shoots.

The NRCC system was more objective because the defoliation of a shoot had to match a picture thus eliminating some bias.

The NRCC system emphasizes the presence of buds. A tree that has a full complement of buds is healthier than a tree missing a third of its buds even though it may have had three times as much current defoliation.

Our bias during postspray sampling in selecting branches with at least one live terminal shoot probably lowered the index an undue amount in comparison to the prespray index when we took any midcrown terminal for sampling. The bias was needed in our case because we were comparing methods of evaluating defoliation rather than trying to determine impact of treatment on tree vitality.

We had difficulty evaluating prespray vitality because most trees had been defoliated four or five successive years, so that a dead tip (class 12) could have been dead for two years. Shoot elongation was nil in some years so that only a cluster of buds remained if all old buds had not unfolded. Some branches, built up from adventitious buds, did not display a definite terminal.

CONCLUSIONS

The Canadian (NRCC system) and the conventional method for evaluating defoliation of balsam fir gave equal average values. The NRCC system also provided a way for estimating backgeeding, but we did not get positive values (zero and negative values mean no backfeeding) because budworm populations were too low to cause backfeeding in the areas which were sampled.

Although field crews had more work to do in using the NRCC system than in the conventional method, we determined from it that tree vitality increased (the index decreased) in the sprayed blocks. The conventional method could be used only for defoliation estimates. The index to tree vitality, based on number of terminal buds and presence of new foliage, were more objective than the usual subjective evaluation that depends mostly on the experience of field crews.

Table 1 -- Defoliation and Vitality Index of Sample Trees Treated for Spruce Budworm Control, Maine, 1976

		Percent Defoliation		Vitality Index	
Treatment	Block	Conventional	NRCC	Prespray	Postspray
Dylox 4	3	24	25	50	25
	6	69	67	37	33
	7	29	27	37	11
Sevin 4 Oil	1	12	9	64	4
	5	41	38	55	25
	10	51	45	60	30
Orthene Forest Spray	2	5	4	54	17
	9	23	23	77	20
	11	23	16	47	10
Check	4	50	44	68	25
	8	62	56	62	29
	12	48	43	43	18

LITERATURE CITED

Dorais, L. G. et Y. J. Hardy, 1976. Evaluation de la protection accordie au sapin, par les pulverisations aeriennes centre la Tordeuse de bourgeons de l'e pinette. Can. J. For. Res. 6: 86-92.

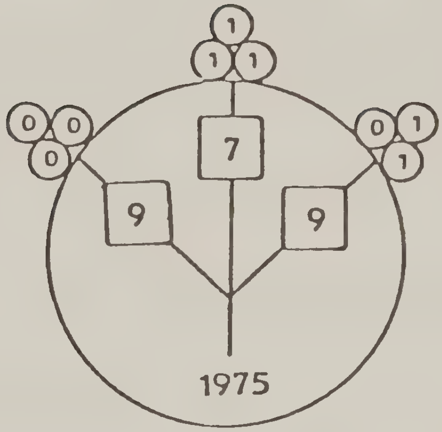
Fettes, J. J., 1950. Investigations of sampling techniques for population studies of spruce budworm on balsam fir in Ontario. For. Insect. Lab., Sault Ste. Marie, Ont. Annu. Tech. Rep.

Block 9   Tree No. 5A   Chemical Orthene Forest Spray

Prespray Date
June 1,

Percent Buds Absent
44

$\bar{X}$ Fettes Class
1975 $\frac{8}{75\%}$



PRESPRAY

Index$_5$

$\frac{3(44)+75}{4} = 52$

Backfeeding

(7+4+7)-9+7+9)= 0

Index$_6$

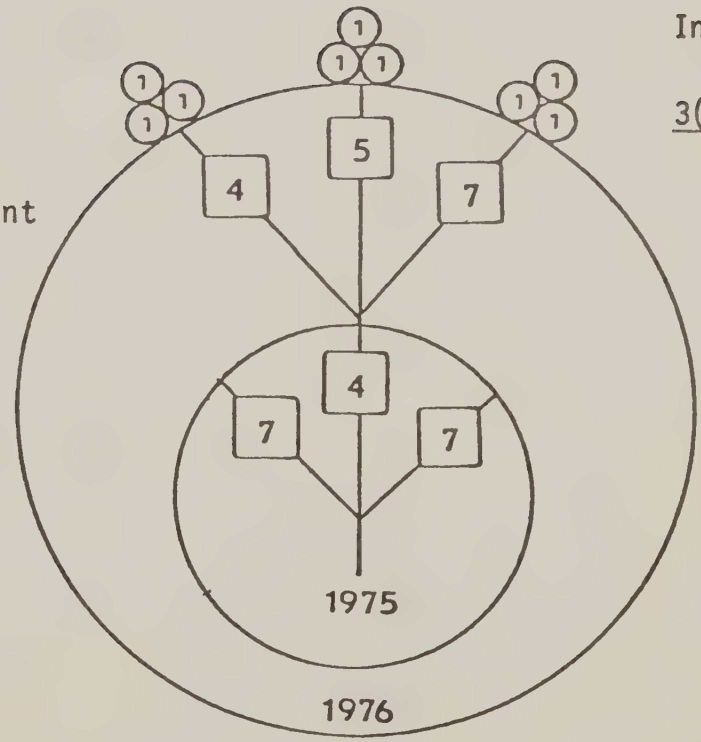
$\frac{3(0)+45}{4} = 11$

Postspray Date
August 25

Percent Buds Absent
0

$\bar{X}$ Fettes Class
1975 $\frac{6}{55\%}$

$\bar{X}$ Fettes Class
1976 $\frac{5}{45\%}$



POSTSPRAY

Figure 1. -- Defoliation schematic. Spruce budworm pilot control project, Maine, 1976.

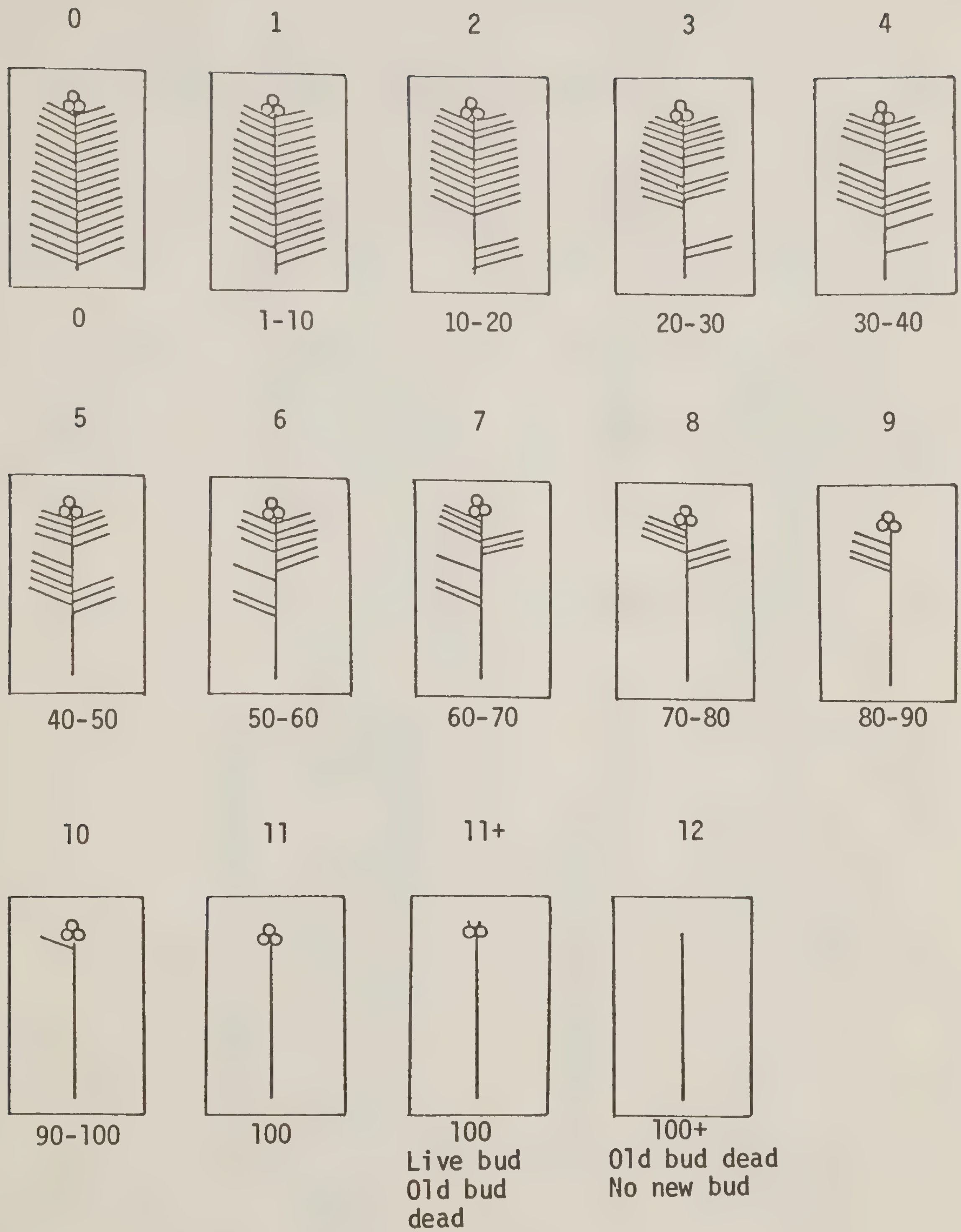


Figure 2. -- Current year defoliation, Fettes classification and percent defoliation. Spruce budworm pilot control project, Maine, 1976.

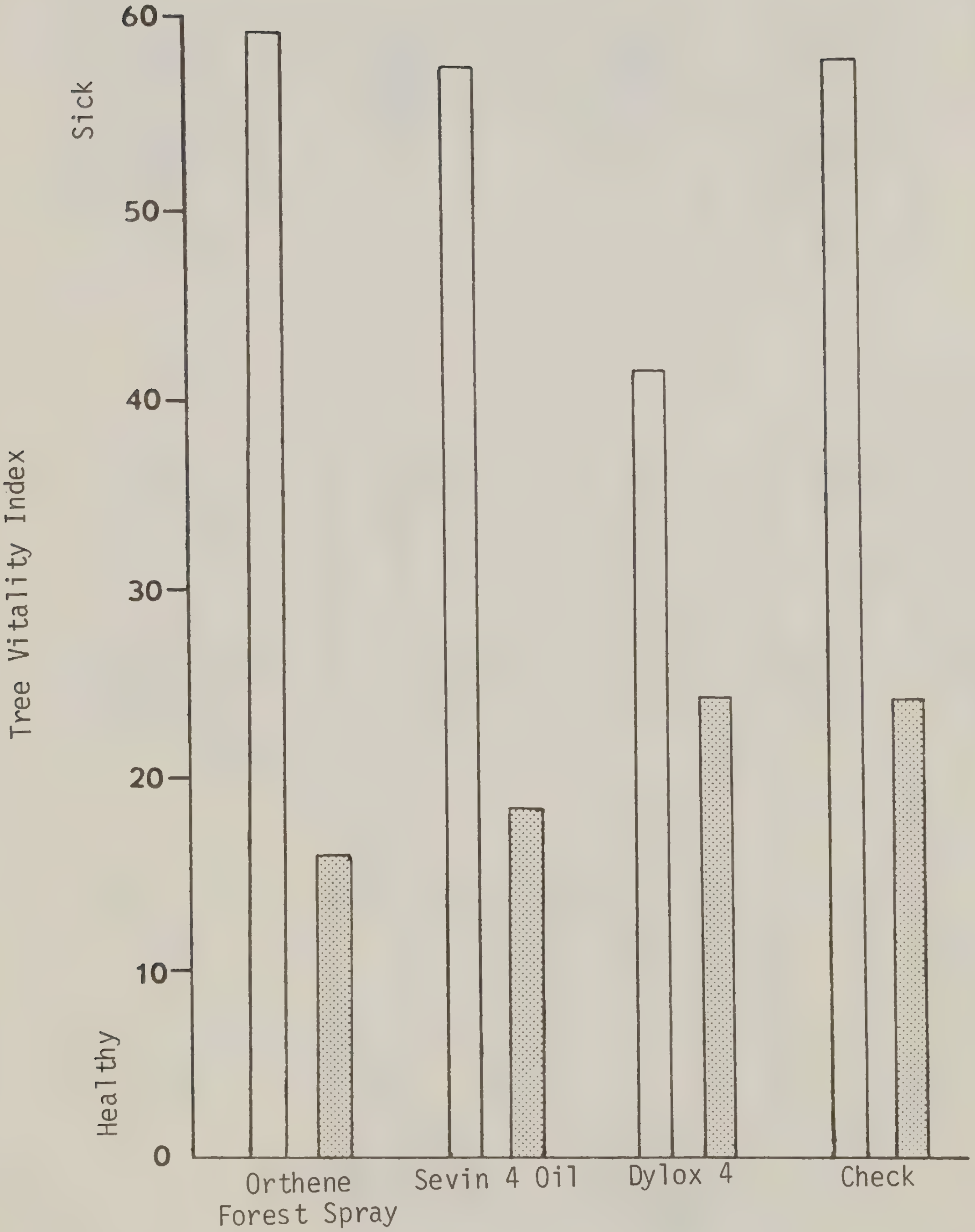


Figure 3. -- NRCC tree vitality index before and after treatment. Spruce budworm pilot control project, Maine, 1976.

Before Treatment After Treatment

CORRESPONDING METRIC AND U. S. VALUES

Page No.	As used in Text	Converted
1, 6, 8, 13, 16	15-inch	38.1 cm
1, 13, 20	64 oz/acre	4.673 l/ha
1, 4, 13, 20	8 oz/acre	559 g/ha
1, 13, 20	12.5 oz/acre	0.913 l/ha
1, 13, 20	4.1 oz/acre	287 g/ha
1, 13, 20	27 oz/acre	1.972 l/ha
1, 13, 20	10.8 oz/acre	756 g/ha
3	one pound/acre	1.12 kg/ha
4	0.5 gallons/acre	4.673 l/ha
4	12 ounces/acre	840 g/ha
4	1 quart/acre	2.336 l/ha
4	1600 acres	648 ha
4	15,840 feet	4828 m
4	4,400 feet	1341 m
5	2 feet by 3 feet	60.96 cm by 91.44 cm
5	100 feet	30.5 m
5	50 feet	15.25 m
5	one yard^2	0.836 m^2
7	1.4-inch	35 mm
11, 20	2,500 acres	1012.5 ha
11	0-2 mph	0-3.218 km/h
11	0-3 mph	0-4.827 km/h
11	2-4; 8 mph	3.218-6.436; 12.872 km/h
11	58-54^{o}F	14-12^{o}C
11	44-48^{o}F	6-9^{o}C
11	69-71^{o}F	20-27^{o}C
15	955 ga	3614.675 l
15	293 ga	1109.005 l
15	25 ga	94.625 l
15	972 ga	3679.02 l
15	297 ga	1124.145 l
15	27 ga	102.195 l
15	2,500 lbs	1132.5 kg
15	121 lbs	54.813 kg
20	175 mph	281.575 km/h
20	40 psi	2.812 kg/cm^2

20	30 psi	2.109 kg/cm^2
20	365 feet	111.25 m
20	100 feet	30.48 m
20	150 feet	45.72 m
20	4800 acres	1944 ha
Appendix A		
3	1600 acres	648 ha
3, 4	15-inch	38.1 cm
Appendix B		
1	4 inches by 5 inches	10.16 cm by 12.70 cm
2	20 feet	6.1 m
2	180 feet	54.9 m
2	100 feet	30.5 m
4, 5, 6	droplets/cm^2	droplets/0.155 in^2
6	1 ounce/acre	11.977 ml/ha
7	17.9 ounces/acre	214.388 ml/ha
7	4.9 ounces/acre	58.687 ml/ha
7	1.5 ounces/acre	17.965 ml/ha
8	8.5 ounces/acre	101.805 ml/ha
8, 9	4 ounces/acre	47.908 ml/ha
8	5 ounces/acre	59.885 ml/ha
8, 9, 12	11.56 ounces/acre	138.454 ml/ha
8, 9, 12	2.1 ounces/acre	25.152 ml/ha
8	9 ounces/acre	107.793 ml/ha
8, 9, 12	7 ounces/acre	83.839 ml/ha
8, 9, 12	1.26 ounces/acre	15.071 ml/ha
9	2 ounces/acre	23.954 ml/ha
11	160 microns (um)	0.0063 in
11	90 microns	0.00354 in
11	136 microns	0.00536 in
11	167 microns	0.00658 in
11	96 microns	0.00378 in
11	139 microns	0.00548 in
11	7 droplets/cm^2	45 droplets/in^2
11	6 droplets/cm^2	39 droplets/in^2
11	4 droplets/cm^2	26 droplets/in^2
11	15 droplets/cm^2	97 droplets/in^2
11	12 droplets/cm^2	77 droplets/in^2
11	10 droplets/cm^2	65 droplets/in^2
12	64 OZ/A	7.665 l/ha
12	12.5 OZ/A	1.497 l/ha
12	27 OZ/A	3.234 l/ha
12	29.49 OZ/A	3.532 l/ha
12	2.74 OZ/A	0.328 l/ha

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife--if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for disposal at surplus pesticides and pesticide containers.

PROTECT

Use Pesticides Safely

FOLLOW THE LABEL

U.S. DEPARTMENT OF AGRICULTURE